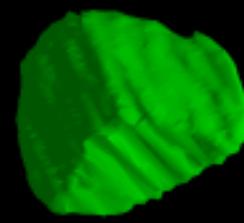
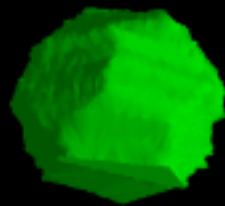
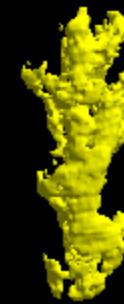


Digital Paleontology: Where's it headed?



Acknowledgements:
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S. Xiao, K. Nealson, A. Tsapin, T. Whiteley
NSF EAR-0236775; NSF EAR-0230142



Trace Fossils

Body Fossils

Climactichnites wilsoni
U. Cambrian Wonewoc Fm., WI



- Biomineralized
- Soft-bodied

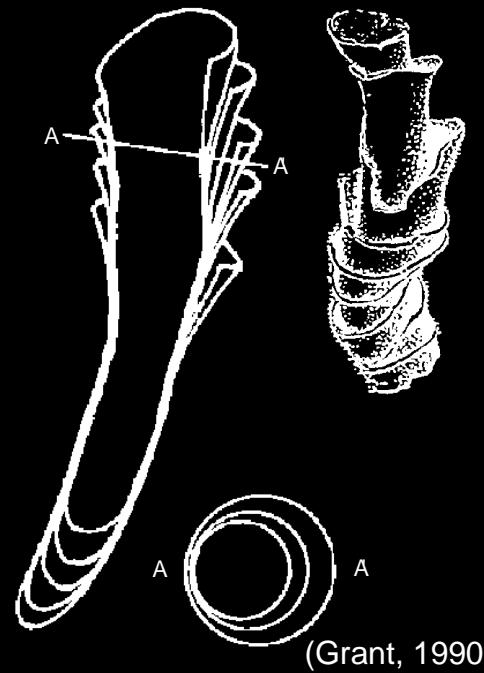
Paraspirifer sp.
Devonian Sylvarena Sh., OH



Sanctacaris uncata
M. Cambrian Burgess Sh, BC
(Photo: D. Collins)

Most entombed in rock!

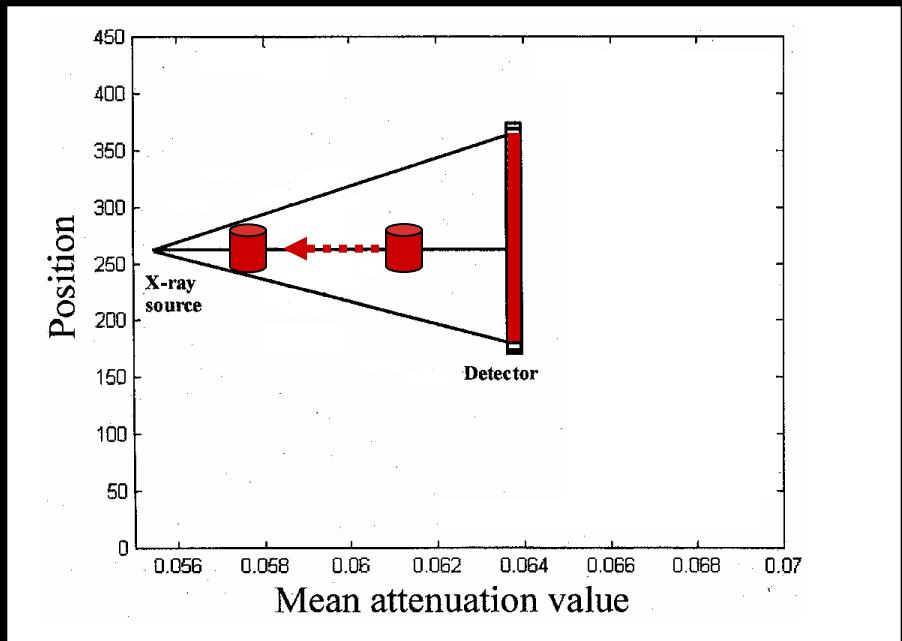
- Chemically/physically extract
- Soft-bodied ~impossible to extract



Cloudina hartmannae
Neoproterozoic La Cienega Fm.
Sonora, MX

Microfocus Computed Tomography

- Bombard sample with highly collimated x-rays
- Rotate sample
- Series of x-radiographic images
- Density, atomic #

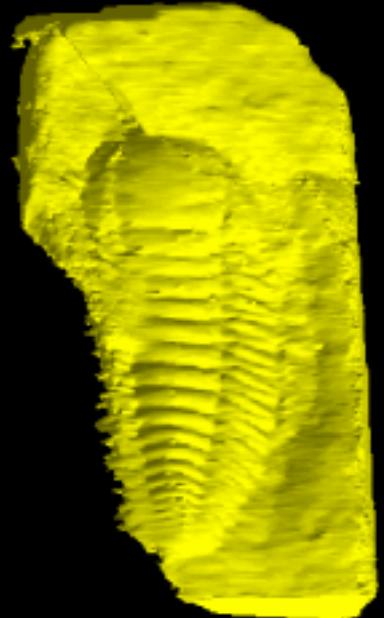
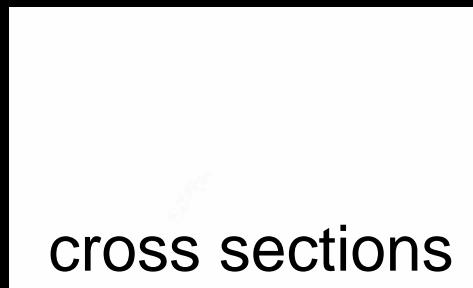


CT Visualization

- Reconstruct x-sectional attenuation plots
 - filtered backprojection
- Stack slices
- Select pixel values
- Contour margins (isosurface)
 - tiling/branching algorithms
- Volume render
 - raycast, raytrace, color



Triarthrus eatoni
U. Ordovician Frankfort Fm, NY

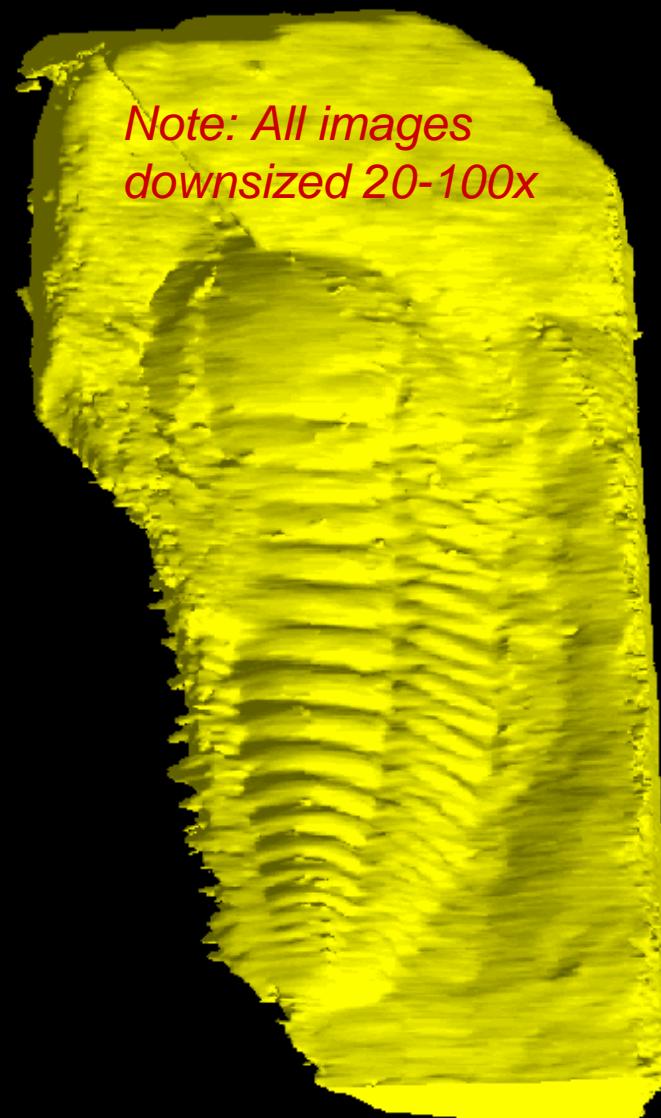


Digital Extraction

X-radiograph
Old dog



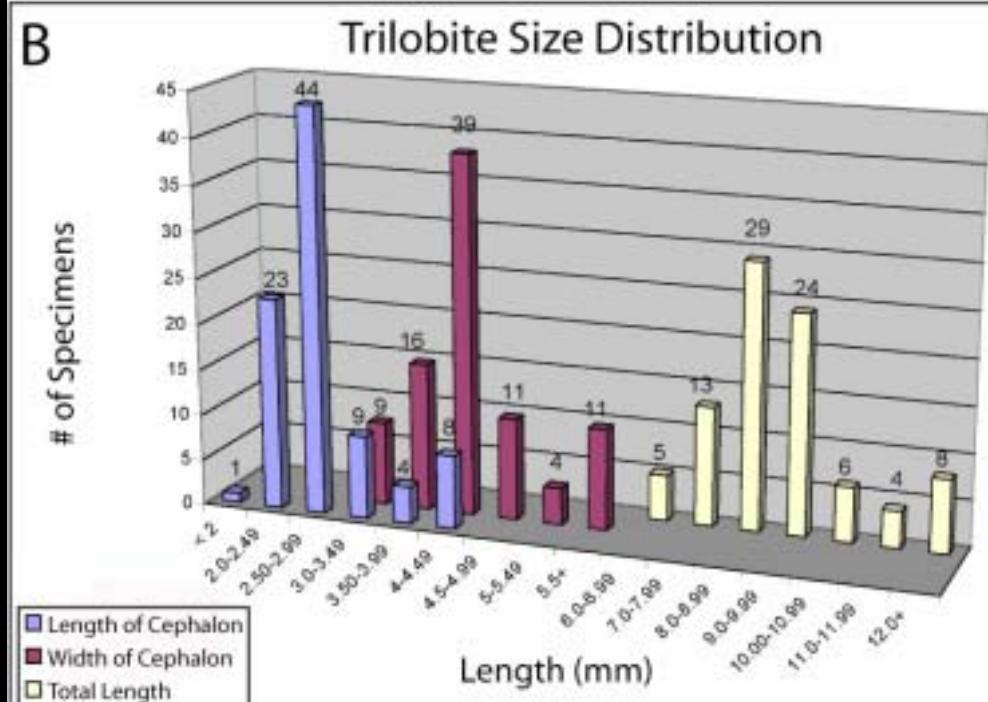
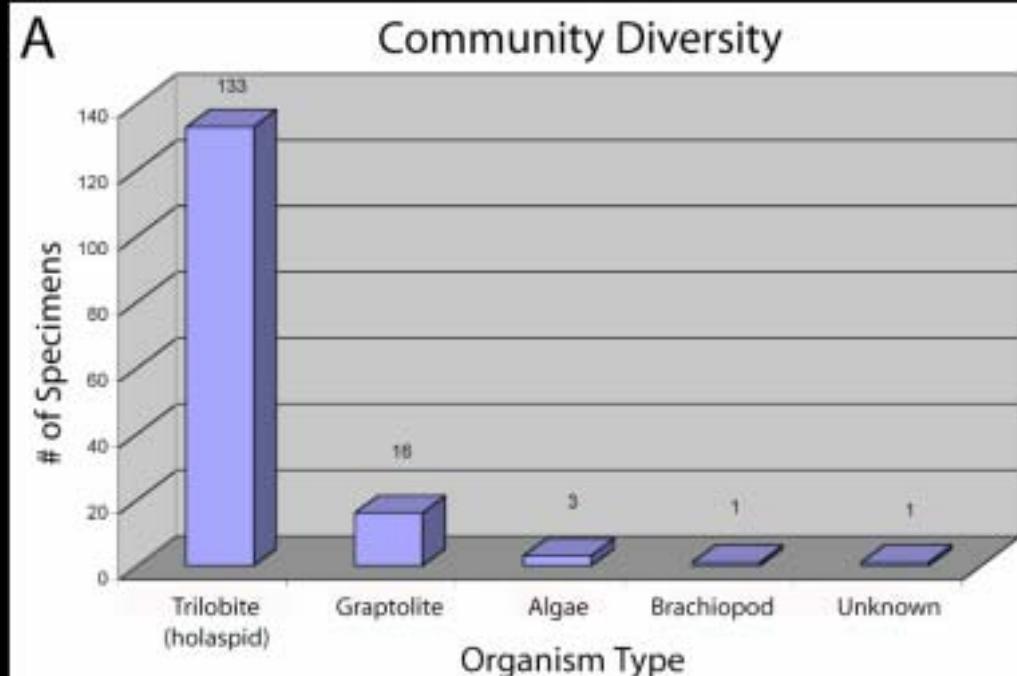
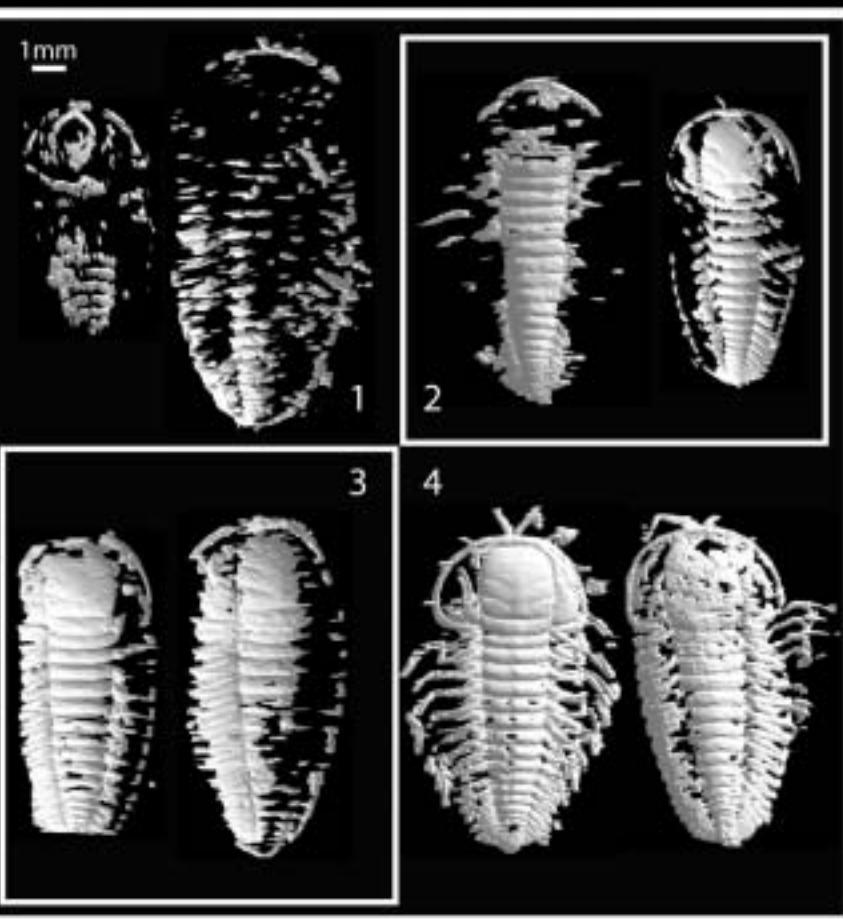
New surface Model
Old dog



1 mm

Forensic, Analytical Tool

- Community structure
- Preservation kinematics



Soft-tissue analysis: Precision & accuracy

- Function of sample size, shape

- Resolution:

$1 \text{ cm}^3 \sim 10 \mu\text{m}$

$1 \text{ mm}^3 \sim 0.5 \mu\text{m}$

- For standards where:

$D_{\text{Quartz}} \sim 2.65$

$D_{\text{Feldspar}} \sim 2.55-2.63$

Specific Gravity	
D_{pyrite}	~ 4.95
$D_{\text{quartz, feldspar}}$	~ 2.65
D_{apatite}	~ 3.1-3.35
D_{dolomite}	~ 2.86-2.93
$D_{\text{cellulose}}$	~ 1.52

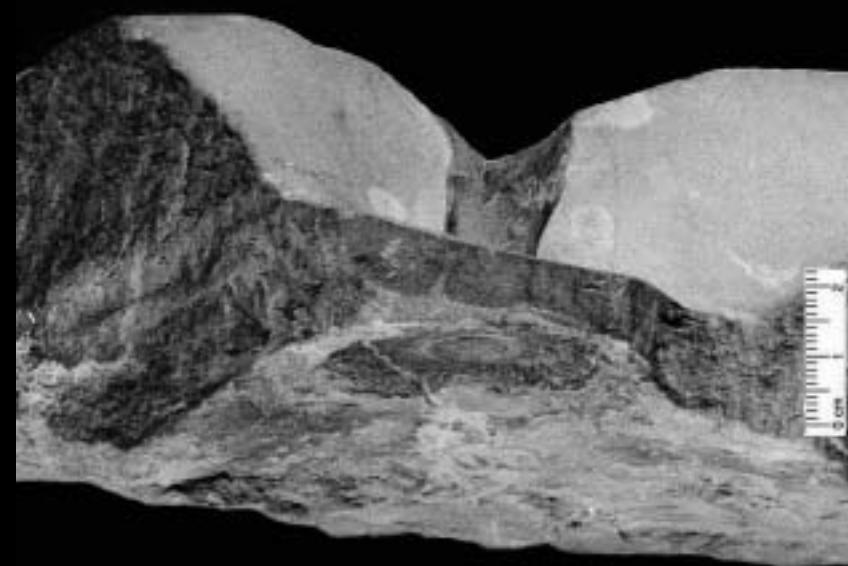
Earliest megafossils are discs

- Medusoid hydrozoans?
- Ctenophores?
- Molluscan egg-cases?



Earliest megafossils are discs

- Pennatulacean holdfast?
- If metazoan, are key test of Snowball Earth hypothesis
- 1001 ways to make discoidal structures



Unnamed charniid
Ust-Pinega Fm., Russia
(Steiner & Reitner, 2001)



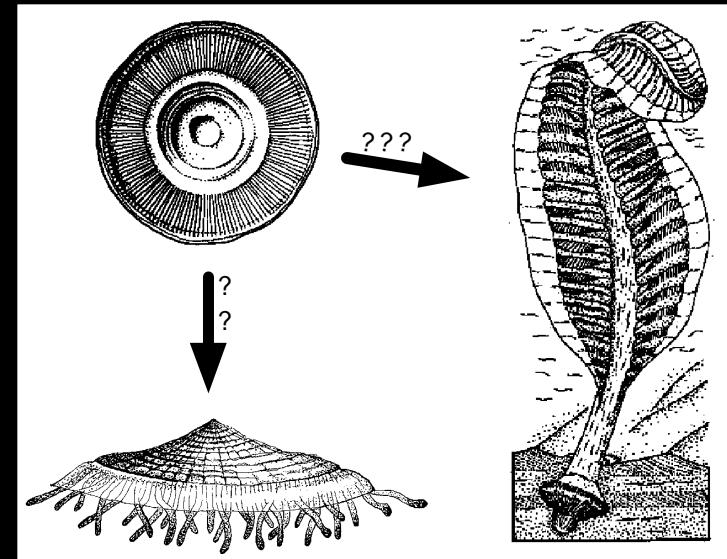
Ediacaran fossils
Mistaken Point, Newf.
(Image: D. Seilacher)

Case Study: Aspidella

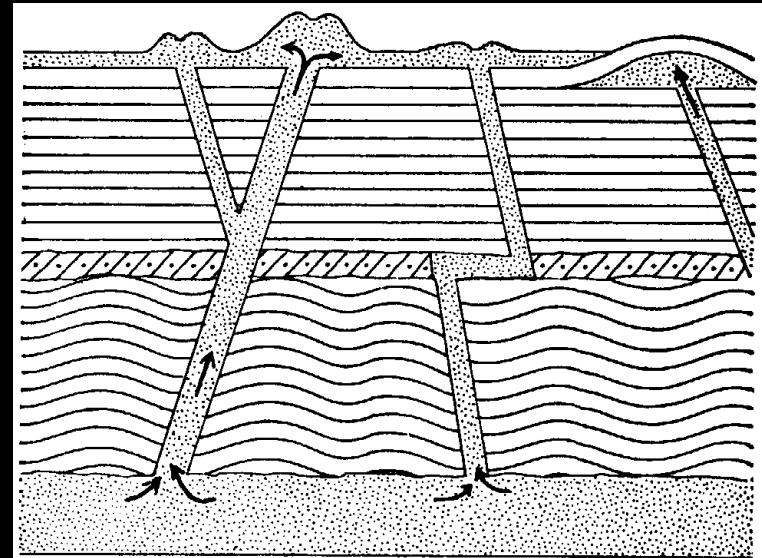
- morphologically simple
- sectioning uninformative
 - lithologically homogeneous



Potential Biological Interpretations



Potential Sedimentologic Interpretations



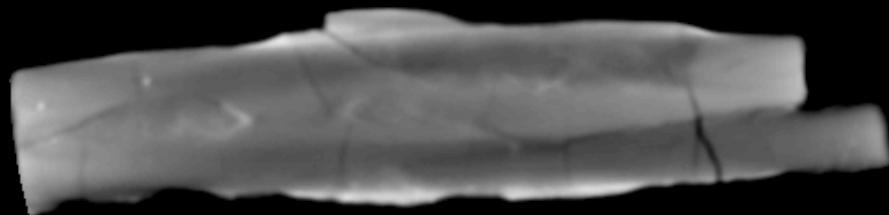
(Ricci Lucchi, 1995)

Case Study: Aspidella

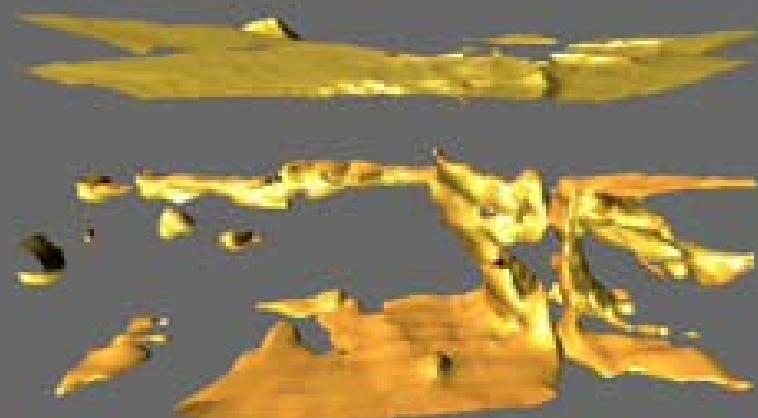
- discs underlain by tube
- 3 of 4 samples



Cross sections

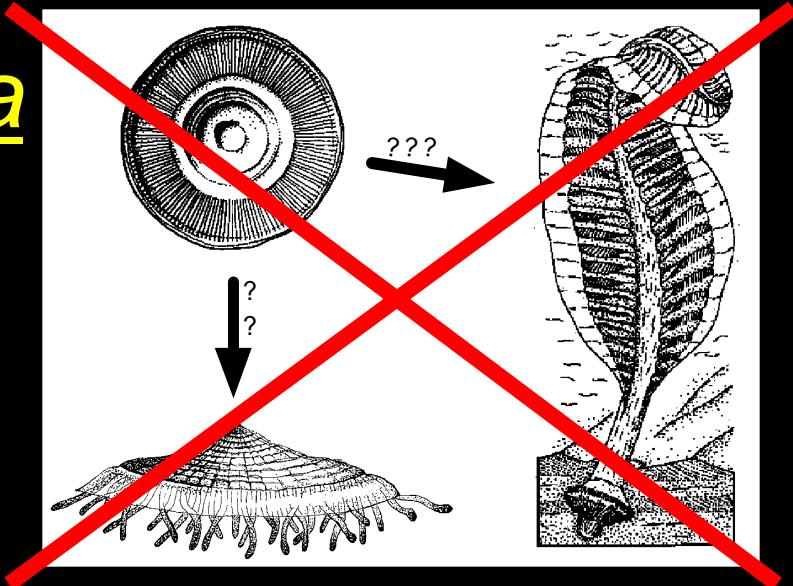


3D reconstruction

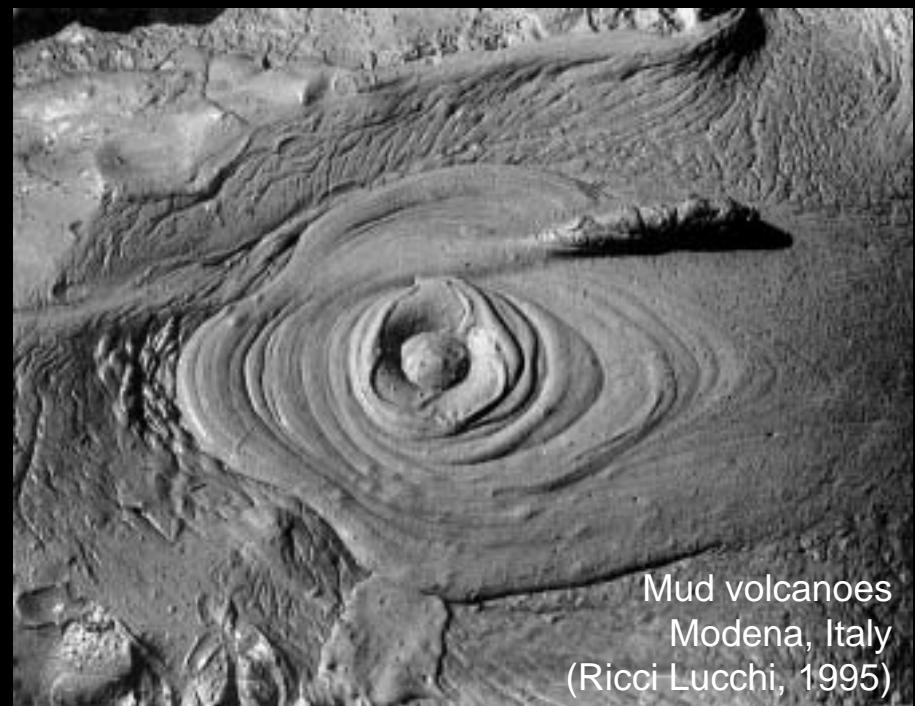


Case Study: Aspidella

- sand/mud volcano

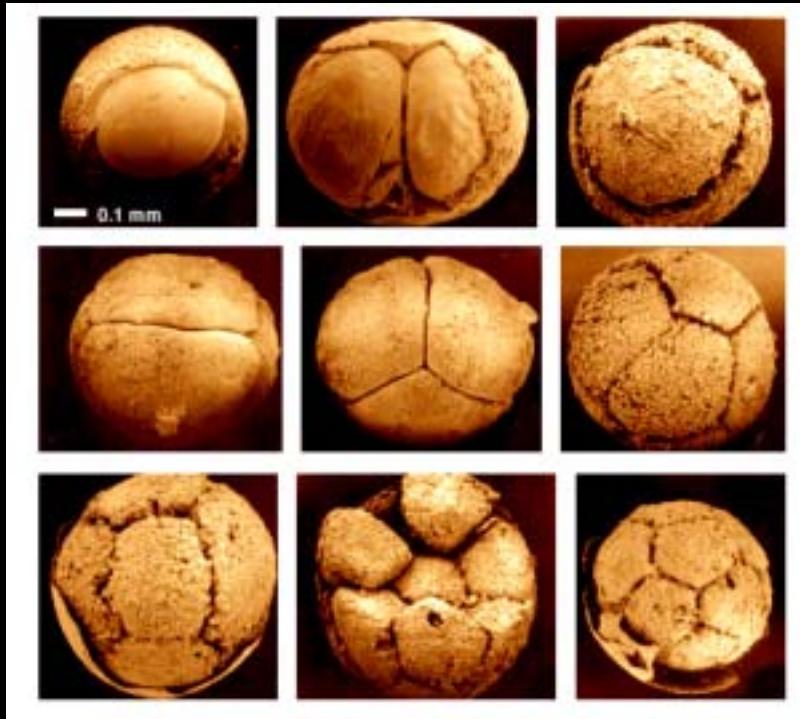


Aspidella sp.
Wood Canyon Fm.,
Salt Spring Hills, CA



Mud volcanoes
Modena, Italy
(Ricci Lucchi, 1995)

Early Animal Embryos



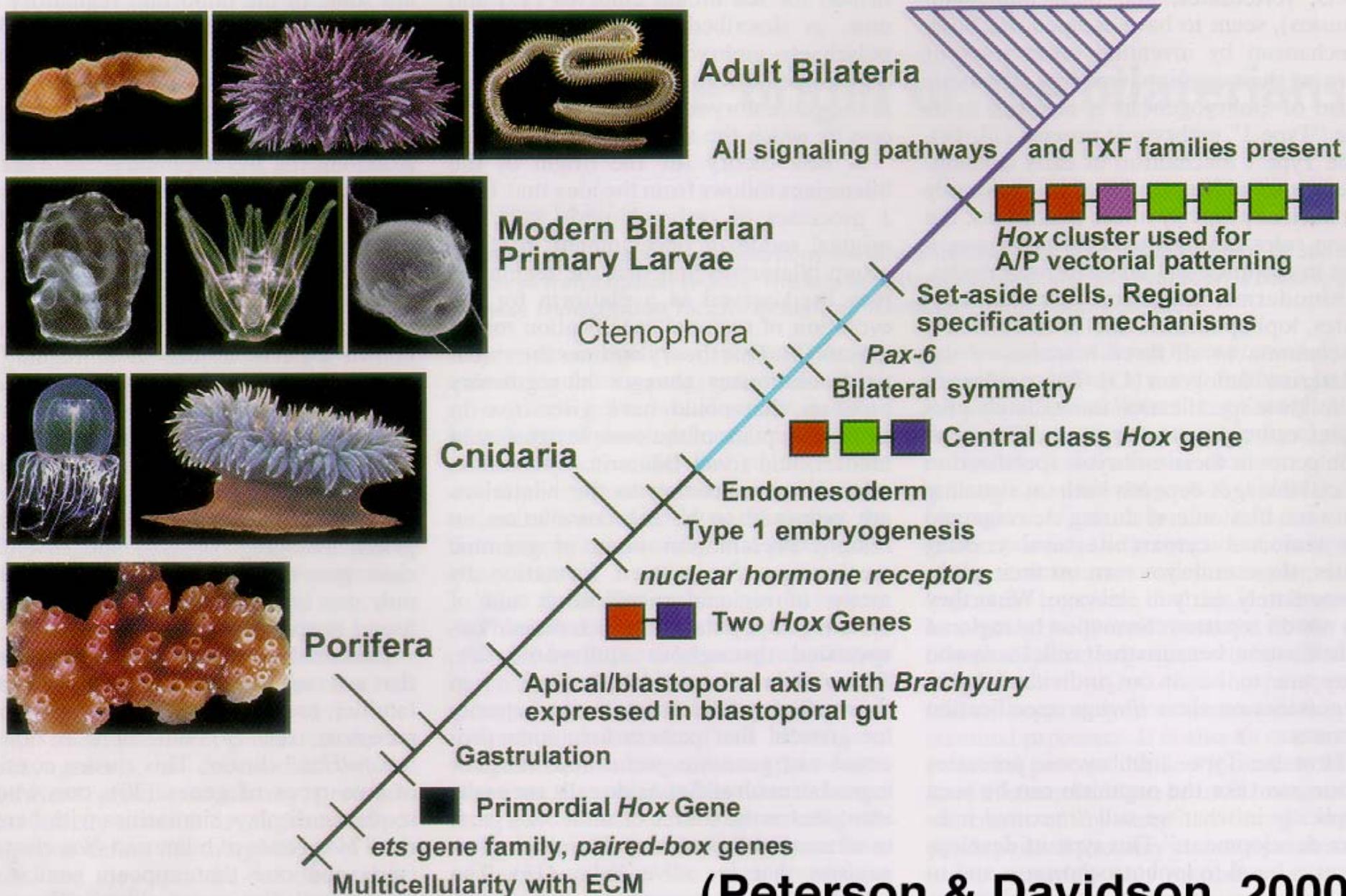
Neoproterozoic Doushantuo Fm., China
(Xiao & Knoll, 2000)



Olivoooides & *Markuelia*
L. Cambrian, Siberia & China
(photo: S. Bengtson)

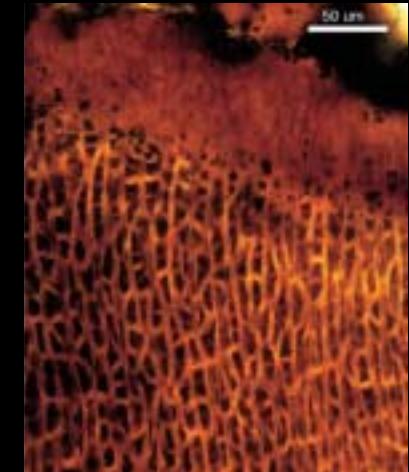
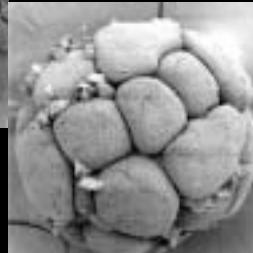
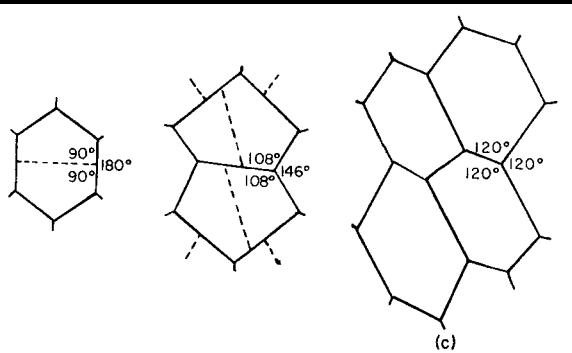
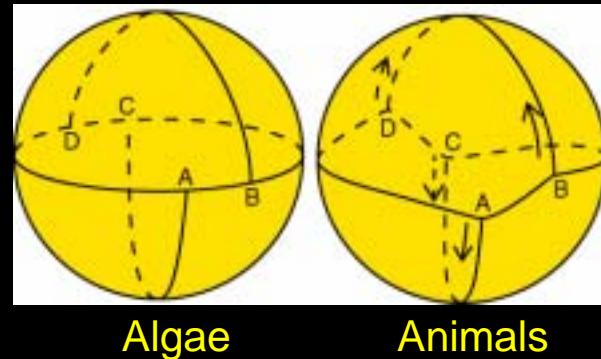
Cell mem., acritarch vesicles, embryo envelopes:
isopachous apatite rim
Cell interiors:
collophane, diagenetic dolomite
Blastomere surfaces:
phosphatic spherules, filaments

Taxonomic affinity?



Animals & Algae:

- Cell division topology, mechanics
- SEM, thin sections



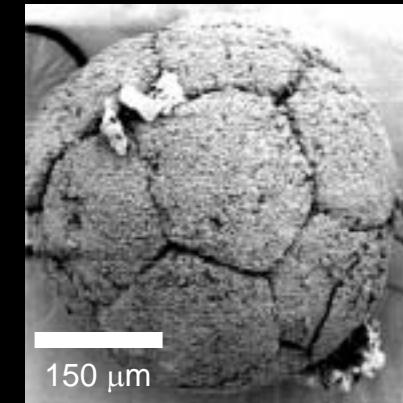
Images: S. Xiao

16-cell *Parapandorina raphospissa*:



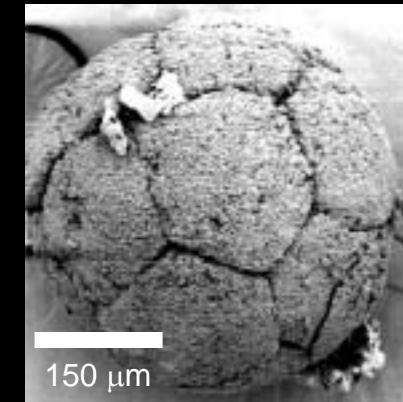
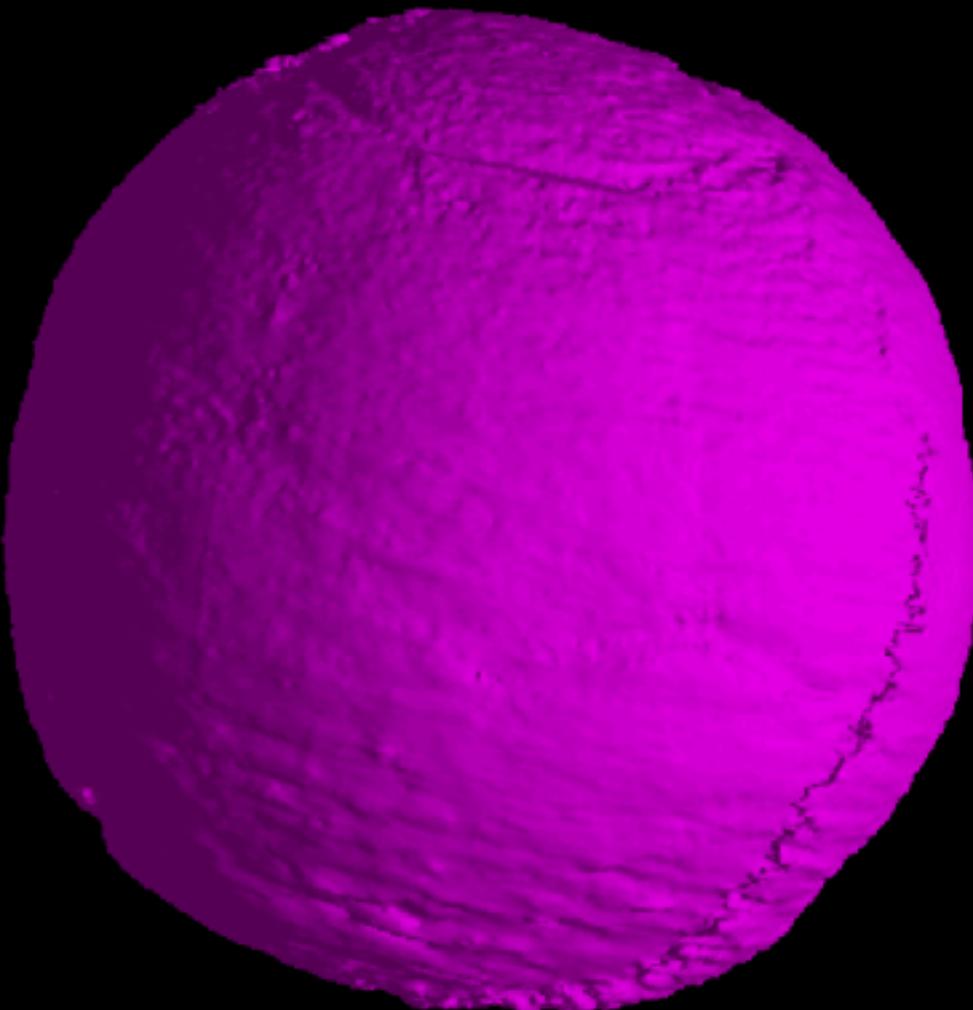
Cross sections

Darker -> greater attenuation



- cell membranes denser
- 16 cells

16-cell *Parapandorina raphospissa*:



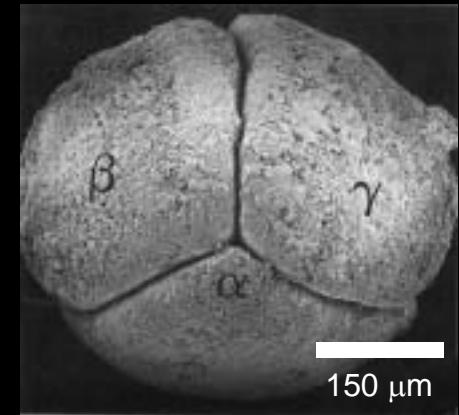
Isosurface model

- faceted cells
- flat, irregular pentagonal faces
- cell face intersections Y-shaped
- ~15 sided polyhedrons

4-cell *Parapandorina raphospissa*:

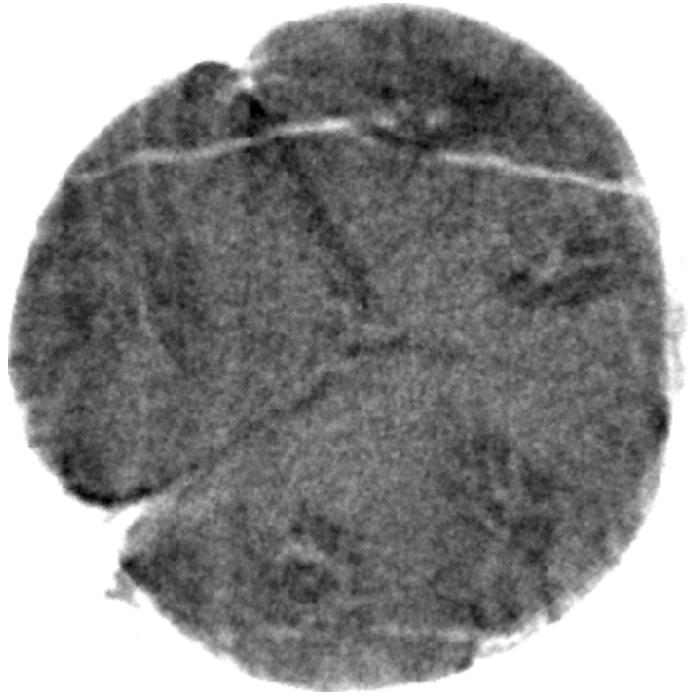


Cross sections



- cell membranes denser
(acic ap xtl vs. random P min)
- paired dense spheroids
*(don't extend beyond cell mem.,
don't touch one another)*

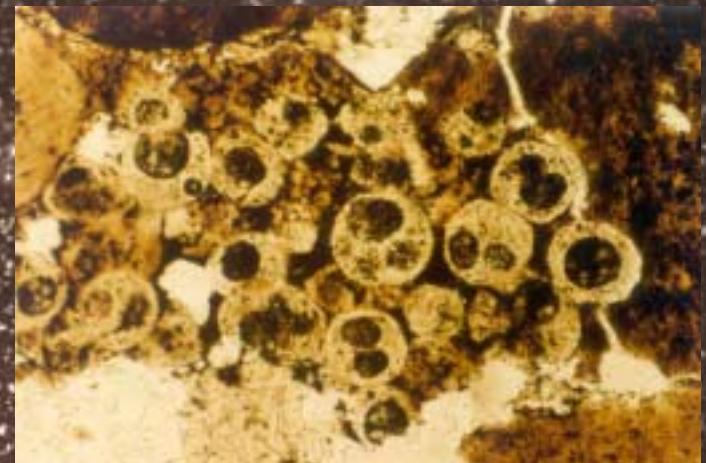
4-cell *Parapandorina raphospissa*:



Cross sections

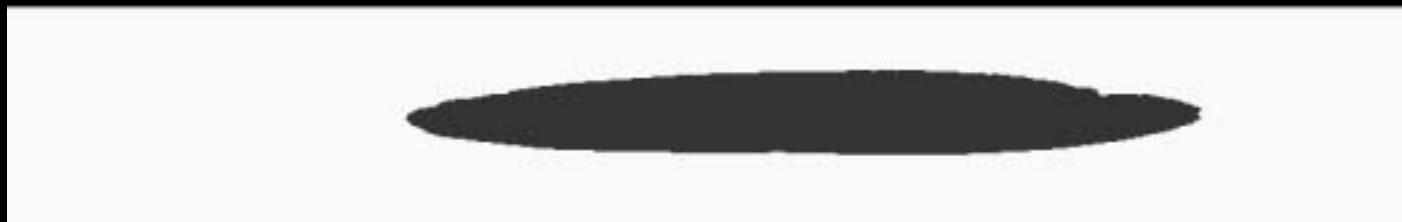


- nuclear division pre-cytokinesis?
thin-section
plane-polarized light
- condensed cytoplasm?

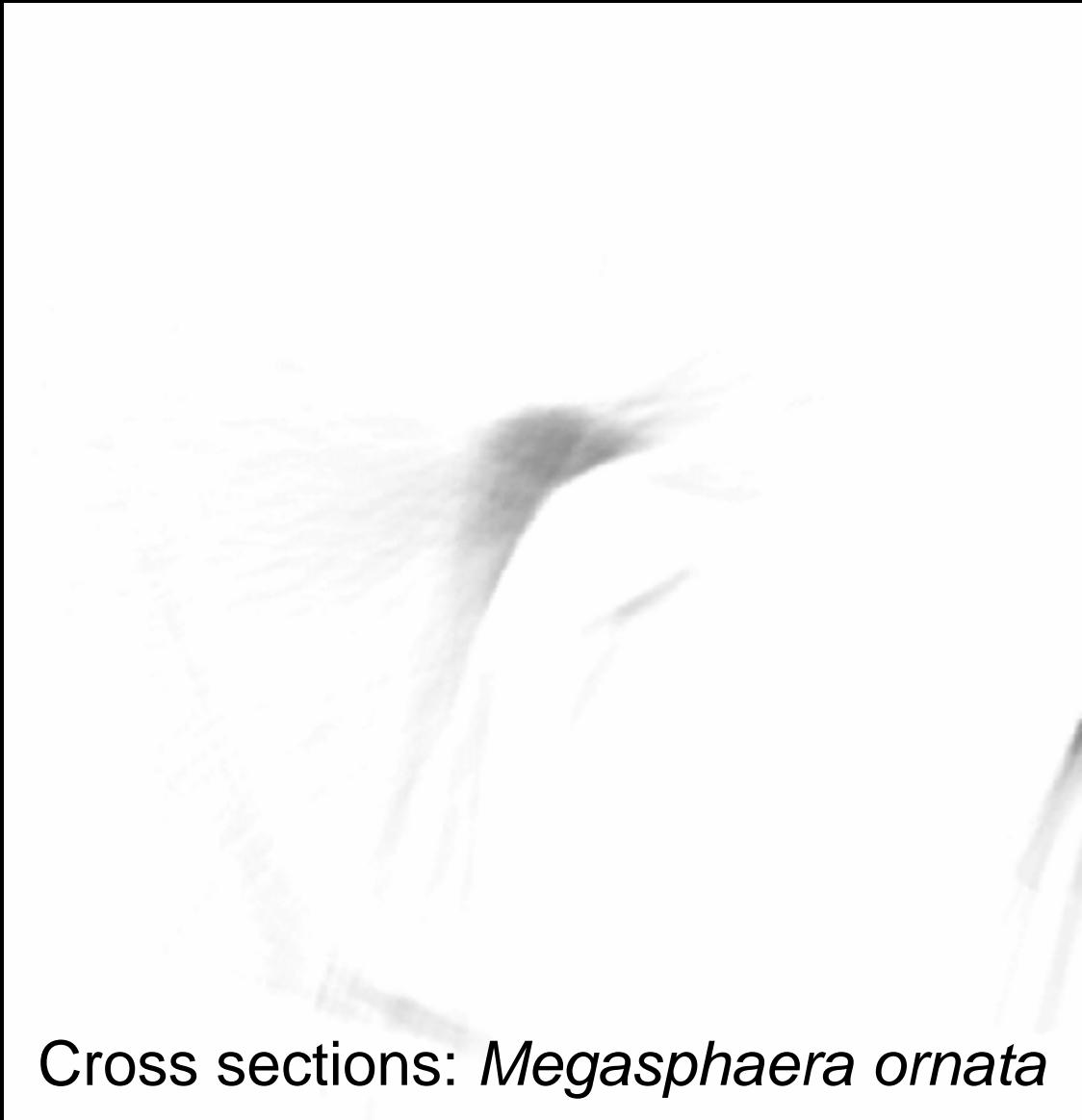


thin-section
cross-polarized light

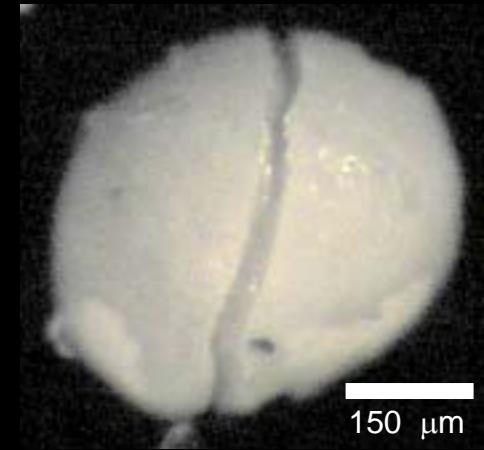
4-cell *Parapandorina raphospissa*:



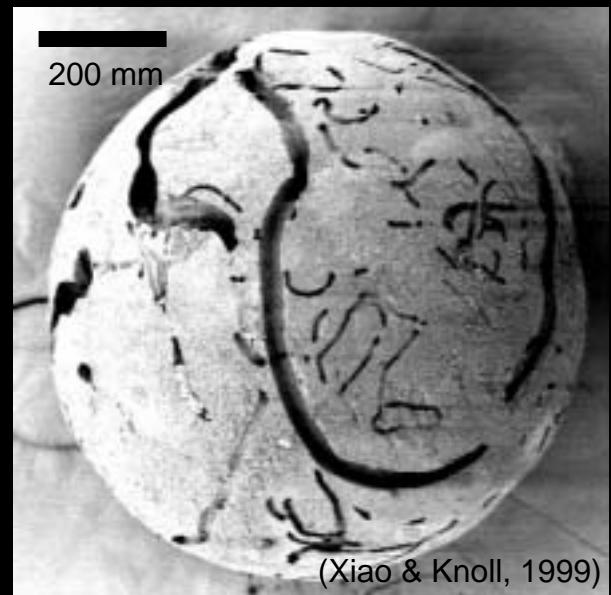
Inorganic features:



Cross sections: *Megasphaera ornata*

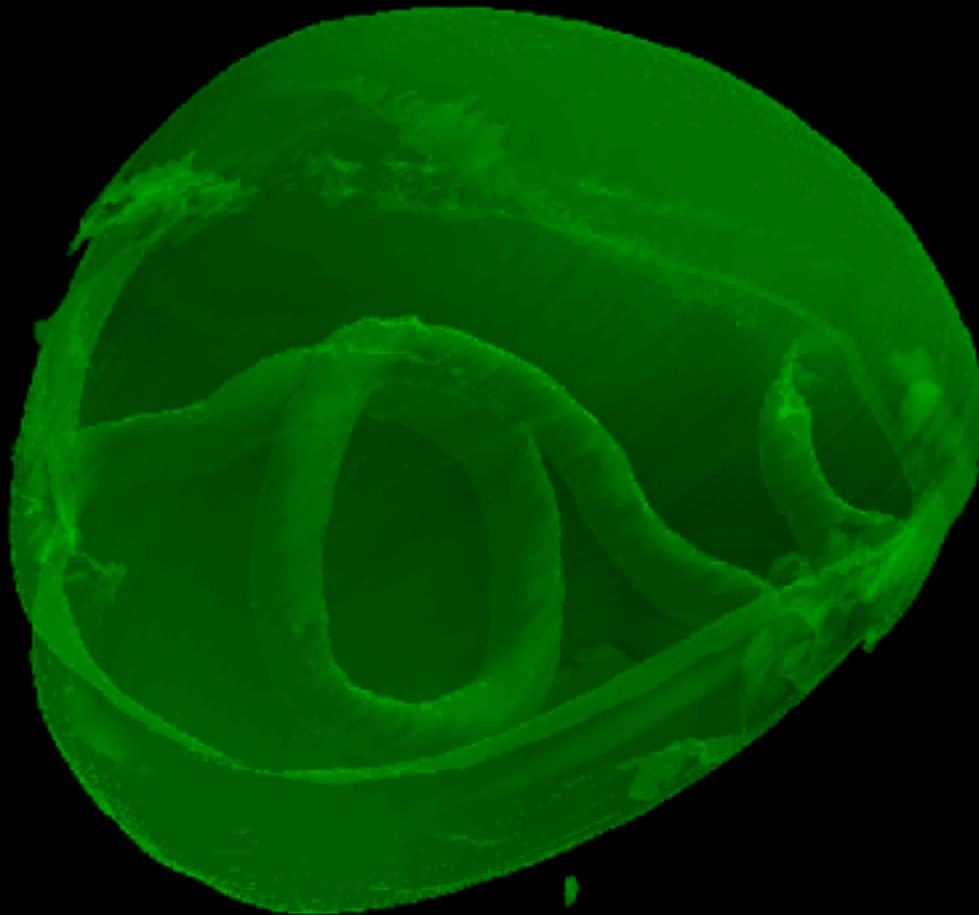


- enigmatic microtunnels
(*pyrite dissolution*)
- shape, spatial relationships?

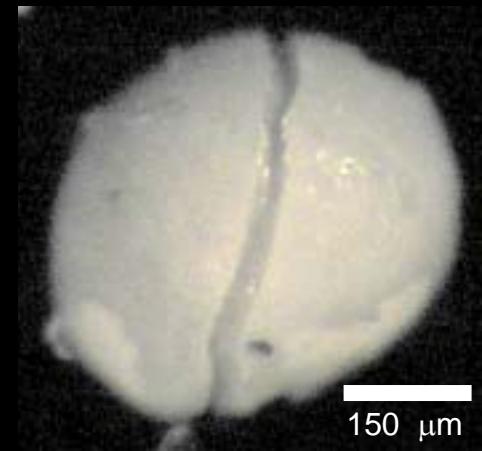


(Xiao & Knoll, 1999)

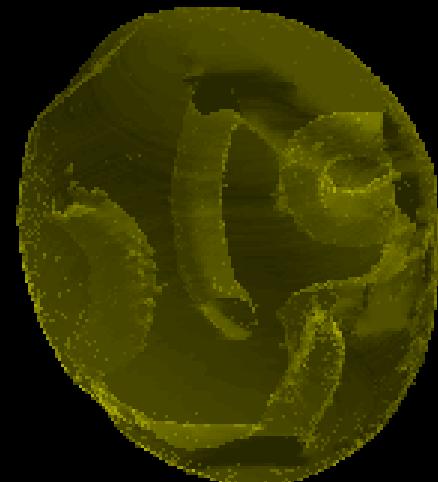
Inorganic features:



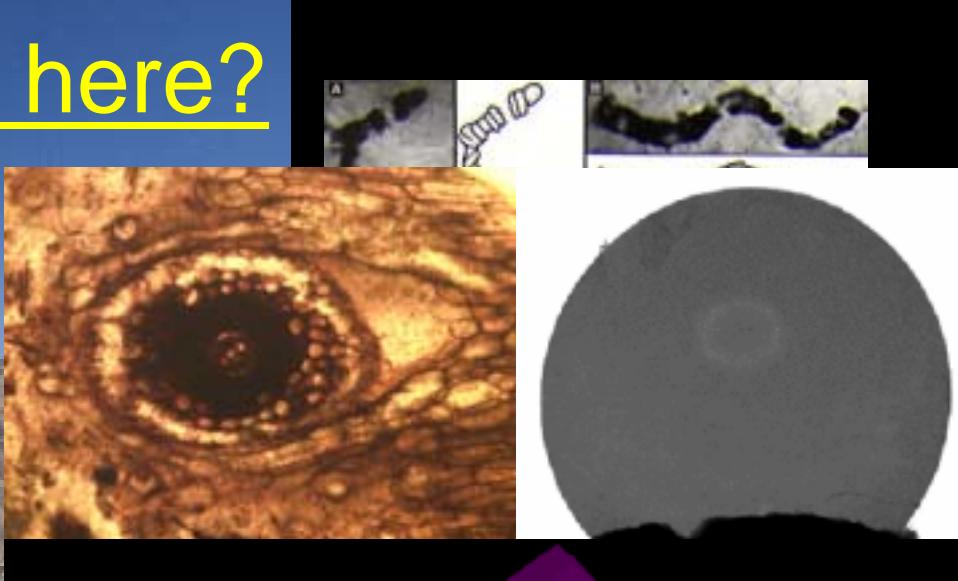
Isosurface model (transparent)



- enigmatic microtunnels
(pyrite dissolution)
- shape, spatial relationships?
(cross-cut, multiple tunnels)



Where do we go from here?



2D/3D element mapping

The Precambrian

Mars



Chromite Distribution within the Allan Hills Meteorite

